Disequilibrium Mapping in High Grade Metamorphic Rocks – Implications for 'Pseudosection' Modeling

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In metamorphic petrology, equilibrium thermodynamics has been largely used as a theoretical framework to compute isochemical phase diagrams also known as 'pseudosections'. In addition to thermobarometry, forward equilibrium models permitted the investigation of multi-scale geochemical cycles linked to lithospheric processes such as mineral reactions and partial melting. However, most of the metamorphic minerals in nature exhibit compositional zoning suggesting sluglish diffusion and only partial re-equilibration. Where such relics are present, thermodynamic "global" equilibrium clearly was not atteined during the evolution of the rock. This simple observation raises questions about the limits of equilibrium models. Is the bulk rock composition of a sample representative of a reactive volume at any stage of the P-T path? If equilibrium is only achieved locally, what are the size and the geometry of the equilibrium volumes that have to be considered for modeling?

To answer these questions, we analyzed the spatial distribution of mineral phases and their compositional zoning in high grade rocks using high-resolution compositional mapping. Local bulk compositions were obtained for specific domains and used as input in the forward models. We used the software BINGO-ANTIDOTE, which readily handles quantitative maps and uses THERIAK to perform Gibbs free energy minimizations. The investigation of two metapelite samples from the Central Alps (peak conditions of ~650 °C) and from the Himalaya (~800 °C) shows that these rocks did not reach global thermodynamic equilibrium during their metamorphic history. By combining compositional maps and Gibbs free energy minimizations, it is also possible to quantify how far, in energy, a mineral – or a specific growth zone of a mineral – is from the assemblage stable at peak conditions. The resulting map displays the degree of equilibrium and disequilibrium of a given rock in a textural context. The effects of disequilibrium on conventional 'pseudosection' modeling can also be tested and quantified.